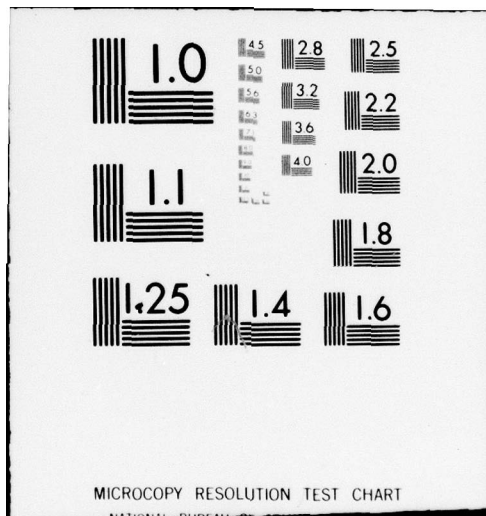


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EXTENDING THE USEFUL LIFE OF DYE-2 TO 1986. PART I: PRELIMINARY--ETC(U)  
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Special Report 79-27

July 1979

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# EXTENDING THE USEFUL LIFE OF DYE-2 TO 1986

## PART I: PRELIMINARY FINDINGS AND RECOMMENDATIONS

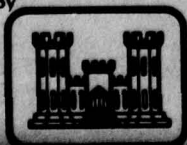
Wayne Tobiasson, Charles Korhonen and Robert Redfield

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UNITED STATES AIR FORCE

By



UNITED STATES ARMY  
CORPS OF ENGINEERS  
COLD REGIONS RESEARCH AND ENGINEERING LABORATORY  
HANOVER, NEW HAMPSHIRE, U.S.A.



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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) DEW Line Ice Cap Station DYE-2 appears to need major work within the next few years to extend its useful life to 1986. The structural steel frame is overstressed in a few areas and the lower portion of the subsurface timber truss enclosure is in bad condition. Additional performance measurements are needed during 1979 to determine the rate of secondary stress in the structural steel frame and the rate of deterioration of the truss enclosure. With this information a decision can be made whether to		

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20. Abstract (cont'd)

Cont' → move the building sideways onto a new undistorted foundation or to stabilize it in-place by encapsulating the lower 52 ft of the substructure in ice. ↗

## PREFACE

This study was conducted by Wayne Tobiasson, Charles Korhonen and Robert Redfield, Research Civil Engineers, Civil Engineering Research Branch, Experimental Engineering Division, U.S. Army Cold Regions Research and Engineering Laboratory.

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Edward Lobacz, Herbert Ueda and Dr. Malcolm Mellor, of CRREL, technically reviewed this report.

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These conversion factors include all the significant digits given in the conversion tables in the ASTM Metric Practice Guide (E 380), which has been approved for use by the Department of Defense. Converted values should be rounded to have the same precision as the original (see E 380).

Multiply	By	To Obtain
inch	0.0254*	meter
foot	0.3048*	meter
foot-kip	1355.818	newton-meter
kip (1000 lbf)	4448.222	newton
gallon (U.S. liquid)	0.003785412	meter <sup>3</sup>

\*Exact

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## EXTENDING THE USEFUL LIFE OF DYE-2 TO 1986

### Part I: Preliminary Findings and Recommendations

By

Wayne Tobiasson, Charles Korhonen and Robert Redfield

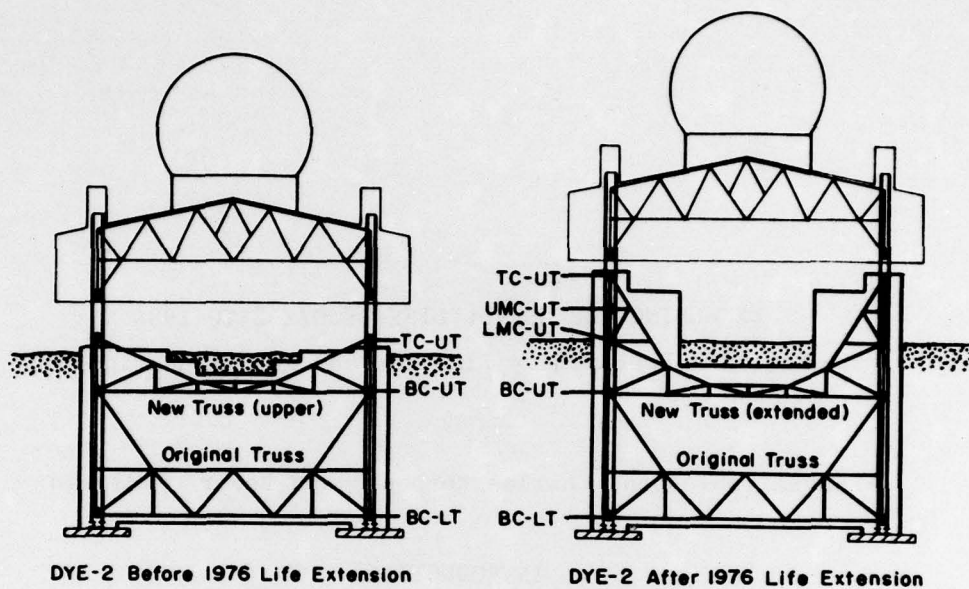
#### INTRODUCTION

A major construction effort within the next few years appears necessary to extend the useful life of DYE-2 to 1986. Performance surveys and stress measurements made at DYE-2 over the past several years by CRREL indicate that the structural steel frame of the building (i.e. footings, columns and trusses) and the timber truss enclosure, are the two key elements that limit the useful life of DYE-2. The current condition and projected future condition of the steel frame and the truss enclosure are discussed in this report and recommendations are made for additional on-site investigations. Several life extension alternatives are discussed. They range from in-place repair or replacement to a sideways move similar to that accomplished at DYE-3 in 1977.

#### STRUCTURAL FRAME

Elevation views of the DYE-2 structural system before and after the 1976 life extension operation are presented in Figure 1. In 1972, 1975 and 1977 we measured forces within the DYE-2 structural frame at essentially all sway bolt interaction points. The technique used is described in CRREL Special Report 205 (Tobiasson, 1974). In addition, we made similar measurements at three "check" locations in 1973, 1974, 1976 and 1978. The 1976 measurements were made just after the life extension operation that year.

Loads on all truss collars were summed each year. Each value was divided by the 1972 sum to generate a normalized "load factor." The resulting "load factors" are presented in Figure 2. The solid line and open circles in Figure 2 represent data from the comprehensive sway bolt measurement program. The dashed line and closed circles represent data from the three check collars read each year. Both curves suggest that the level of secondary stress in the structural frame is stabilizing. Because comprehensive measurements have been taken only once since the 1976 life extension operation, it is somewhat risky to extrapolate this trend all the way to 1986. However, it can be said that the structural frame of DYE-2 has not been accumulating secondary stresses as rapidly as the DYE-3 structural frame did during the planning of its life extension.



**LEGEND:**

TC-UT Top Collar-Upper Truss  
 UMC-UT Upper Middle Collar-Upper Truss  
 LMC-UT Lower Middle Collar-Upper Truss  
 BC-UT Bottom Collar-Upper Truss  
 BC-LT Bottom Collar-Lower Truss

Figure 1. Elevation views of DYE-2 before and after the 1976 life extension.

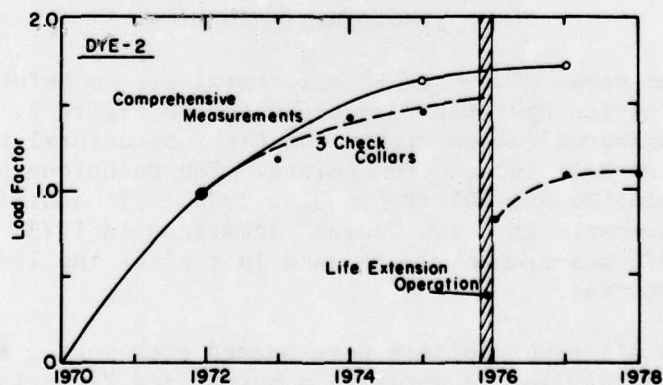


Figure 2. Load factor vs time for both comprehensive sway bolt measurements and measurements at three check collars. The check collars are defined in Table I.

We recommend a comprehensive sway bolt measurement program at DYE-2 for the summer of 1979. Results from that program should allow us to better estimate the current rate of secondary stress accumulation in the structural frame. If those measurements indicate that the rate of stress increase is slight, it may be possible to continue with the existing structural system to 1986.

The significant drop in the load factor shown in Figure 2 for the three check collars after the 1976 life extension operation is of interest. All readings taken of those collars are summarized in Table I. That information indicates that loads in those three collars were altered significantly by the life extension operation.

Since the comprehensive measurements in 1977 (Fig. 2) did not show a post-life-extension decrease, it is evident that the loads lost by the three check collars during the life extension operation were gained by other collars.

Using the comprehensive sway bolt loads measured in 1975, column bending moments have been calculated at the level of each truss collar. These values are presented in Table II. Large bending moments are present at the bottom of all columns (i.e. at the bottom collar of the lower truss).

Similar information generated from sway bolt loads measured in 1977 is presented in Table III. Again, large bending moments are present at the bottom of columns. Comparing Tables II and III, it is seen that there have been significant changes in column bending loads between 1975 and 1977. This is attributed to the 1976 life extension operation.

The allowable load for a column under combined axial compression and bending is controlled by the sum of the effects due to axial compressive stress and bending stress. The equation to determine the allowable combined stress is given in Section 1.6.1 of the AISC Manual of Steel Construction (American Institute of Steel Construction 1970) as follows:

$$\frac{f_a}{F_a} + \frac{f_{bx}}{F_b} + \frac{f_{by}}{F_b} \leq 1.0$$

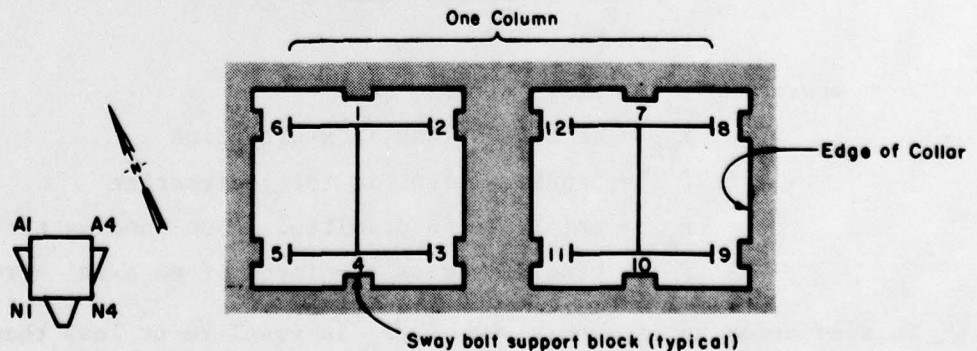
where  $f_a$  = axial stress  
 $f_{bx}$  = bending stress in x-direction  
 $f_{by}$  = bending stress in the y-direction  
 $F_a$  = axial stress permitted if no bending stresses exist  
 $F_b$  = bending stress permitted if no axial stresses exist

This equation applies only when  $f_a/F_a$  is equal to or less than 0.15\*.

\*In 1975 and 1977 respectively,  $f_a/F_a$  averaged 0.10 and 0.11.

Table I. Sway bolt load measurements at the three check collars, DYE-2

Column	Location	Sway Bolt	LOAD IN KIPS*						
			1972	1973	1974	1975	1976	1977	1978
A1	Building level	1	13.9	22.6	23.7	27.4	0	0	0
		5	10.4	9.2	18.1	22.1	0	8.4	22.8
		6	9.7	17.5	20.9	28.6	0	0	0
		7	23.4	27.3	29.3	28.9	1.4	0	0
		11	24.7	30.4	31.5	38.2	16.5	13.0	21.7
		12	22.7	24.5	32.1	23.1	0	15.4	15.9
A4	Lower middle collar - upper truss	1	9.6	14.5	10.4	15.4	0	0	0
		4	0	0	0	0	12.1	59.6	54.8
		5	31.2	31.7	39.9	44.7	12.0	29.8	18.8
		6	46.7	26.0	19.1	24.1	21.2	24.0	24.7
		7	11.5	9.1	5.9	10.1	0	0	0
		8	0	0	0	0	0	8.9	12.3
		9	0	0	0	0	0	19.8	26.5
		10	0	0	0	0	11.4	0	0
		11	0	2.4	14.3	14.0	9.6	0	0
		12	0	9.1	14.5	19.5	18.0	0	0
A2	Bottom collar - upper truss	1	0	10.4	21.7	6.5	11.0	0	0
		2	0	18.0	22.3	18.5	30.2	25.3	33.9
		3	0	14.3	8.4	7.1	20.1	39.3	32.8
		7	13.0	15.6	25.1	12.5	14.9	8.1	5.2
		8	19.5	0	5.8	7.5	11.0	0	0
		9	10.4	6.6	6.6	7.5	15.8	0	15.3
TOTALS			246.7	289.2	349.6	355.7	205.2	270.1	284.7
ANNUAL LOAD INCREASE			42.5	60.4	6.1	-150.5	64.9	14.6	
LOAD FACTOR (1972 DATUM)			1.00	1.17	1.42	1.44	0.83	1.09	1.15

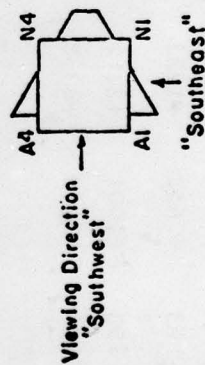


\*Kips denote kilopounds (i.e. 1 kip = 1000 lb).

Table II. Column bending moments calculated from sway bolt measurements in 1975, DYE-2

	A1	A2	A3	A4	N1	N2	N3	N4
<u>Viewing direction: southeast*</u>								
Top collar - upper truss	+1124	+ 960	+1036	- 420	+ 534	- 246	-1134	- 324
Bottom collar - upper truss	+1940	+2081	+2224	- 314	+ 729	- 654	-2697	- 391
Bottom collar - lower truss	+3844	+5760	+4996	+2172	+ 476	-3409	-6359	-1690
<u>Viewing direction: southwest*</u>								
Top collar - upper truss	-2236	-2312	+1204	+1530	-1528	-1130	+ 844	+1812
Bottom collar - upper truss	-2718	-2513	+1346	+ 916	-1658	- 808	- 320	+1536
Bottom collar - lower truss	-8251	- 710	- 194	+1510	-4738	+1656	-1966	+2746

\* See sketch

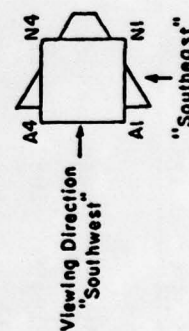


Clockwise moments are positive. Moments are in ft-kips.

Table III. Column bending moments calculated from sway bolt measurements in 1977, DVE-2

	A1	A2	A3	A4	N1	N2	N3	N4
<u>Viewing direction: southeast*</u>								
Top collar - upper truss	0	+ 306	+ 527	- 171	+ 57	- 419	- 392	- 274
Upper middle collar - upper truss	+ 374	+ 345	+ 638	+ 357	+ 68	- 719	- 781	- 820
Lower middle collar - upper truss	- 63	+ 658	+ 1222	+ 1037	- 403	- 1242	- 1143	- 1327
Bottom collar - upper truss	+ 198	+ 1501	+ 2162	+ 862	- 1682	- 2768	- 2105	- 2263
Bottom collar - lower truss	+ 1089	+ 3920	+ 4358	+ 3080	- 5260	- 6727	- 2424	- 5993
<u>Viewing direction: southwest*</u>								
Top collar - upper truss	- 721	- 715	+ 363	+ 1190	0	- 909	+ 692	+ 474
Upper middle collar - upper truss	- 1204	- 994	+ 318	+ 1779	+ 14	- 1250	+ 119	+ 551
Lower middle collar - upper truss	- 1707	- 1123	+ 436	+ 1994	- 321	- 1536	+ 1569	+ 463
Bottom collar - upper truss	- 2761	- 1360	+ 83	+ 1787	+ 109	- 2990	+ 640	+ 168
Bottom collar - lower truss	- 5634	+ 2739	- 3546	+ 2818	- .74	- 6092	- 4070	+ 168

\*See sketch



Clockwise moments are positive. Moments are in ft-kips.

This equation has been solved for the combined stresses at the bottom collar of the lower truss (i.e. essentially the base of the column) and the bottom collar of the upper truss (i.e. about 52 ft above the base of each column) in 1975 and 1977. Results are presented in Table IV. Where the result exceeds 1.0, the column is overstressed. A value of 2.36, as was present at A1 in 1975, indicates that combined stresses at that location are 2.36 times the maximum value allowed by AISC. Where the factor exceeds 2.0, overstress is so great that the likelihood of plastic yielding is introduced. Some plastic yielding was noticed at the base of one of the DYE-3 columns prior to the sideways move in 1977.

The following conclusions can be drawn from Table IV:

- In 1975 there was significant overstress at the base of column A1.
- In 1977 overstress at the base of column A1 had reduced significantly (2.36 to 1.47) but the base of column N2 had become highly overstressed (0.92 to 2.28), probably as a result of the 1976 life extension program.
- Six of the eight columns were overstressed at their base in 1977.
- Only column N2 was overstressed at the bottom collar of the upper truss in 1977 and the overstress there was not alarming, only 12%. All other columns were stressed to levels well below allowables at the bottom collar of the upper truss in 1977.

Table IV. Combined Load Factors, DYE-2

<u>Column</u>	Bottom collar - lower truss (i.e. near column base)		Bottom collar - upper truss (i.e. about 50 ft above base)	
	<u>1975</u>	<u>1977</u>	<u>1975</u>	<u>1977</u>
A1	2.36	1.47	0.94	0.74
A2	0.98	1.18	0.91	0.58
A3	0.78	1.44	0.69	0.43
A4	0.66	1.09	0.31	0.59
N1	1.12	0.83	0.49	0.30
N2	0.92	2.28	0.38	1.12
N3	1.29	1.28	0.49	0.51
N4	0.91	0.88	0.49	0.41

Overall it is probably not possible to reduce stresses in the structural frame by sway bolt adjustments. However it may be possible to transfer a portion of stresses on highly stressed elements to other elements that are not overstressed. This is an appealing alternative at DYE-2 since most components of the structure are not overstressed and the level of secondary stress does not appear to be increasing much with time.

The biggest factor which stands in the way of using the existing subsurface steel frame to 1986 is failure of the truss enclosure in which it is located.

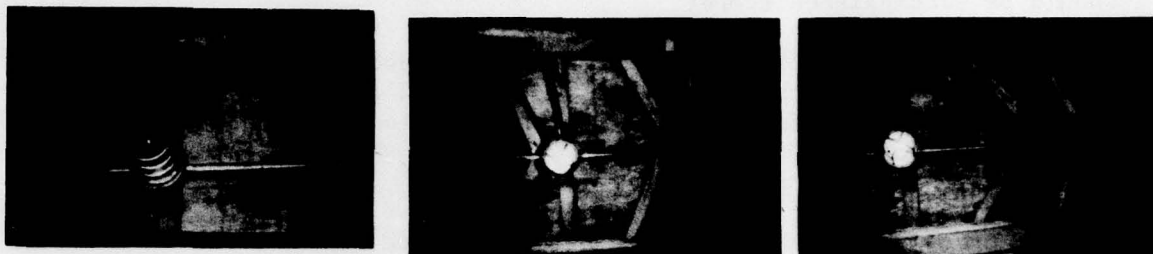
#### TRUSS ENCLOSURE

We have observed the progressive deterioration of the DYE-2 truss enclosure for several years and are convinced it cannot last in its present state to 1986. Based on our annual observations we questioned the partial replacement work done in 1976. At that time the truss enclosure in the N4 corner was replaced to within 20 ft of its base (i.e. down to site elevation 17). Prior to that work, the N4 corner was in bad condition and needed repairs. However major failures had also occurred in the A4 and N1 corners and along the outer A-row. At that time we expected that in a few years other areas of the truss enclosure would become as distressed as the N4 corner at the time of its replacement. This has occurred.

Although the truss enclosure is in good condition above elevation 52, it has many problems below. The A4 corner is badly distorted and is becoming progressively worse. Most wall plates have failed in that area between elevation 22 and 48. The elevation 22 plate has failed all along most of the outer wall of the truss enclosure. This has essentially eliminated all vertical support for the outer walls above, except that available from the snow alongside. Since that snow is consolidating, the wall sections move downward with it much like a collapsing telescope. The outer wall of the A-row has moved downward several inches in most locations. The old portion of the N-row outer wall has not yet been displaced as much as the A-row outer wall but it is also filled with cracks and failed plates which offer little or no resistance to downward movement. The N1 corner is falling apart much like the A4 corner.

The three photographs shown in Figure 3 attest to the fact that the truss enclosure failure mechanism is active up through our last inspection in 1978.

Because of the complexity of the failure-displacement mechanism it is difficult to predict the rate of vertical displacement expected over the next few years. Dial extensometer measurements should be made during the summer of 1979 to help define the rate of downward movement at locations where significant interferences are likely to develop.



1976

1977

1978

Figure 3. The A-row outer wall of the truss enclosure between columns A3 and A4 just below the elevation 26 plate. Note that additional distortions are evident in 1977 and in 1978.

Even the new work in the N4 corner is experiencing problems. All of the elevation 17 plate on which the new portion of the truss enclosure rests was either highly stressed or had failed in 1978. The weight of the new portion and draw-down forces applied to the truss enclosure by the adjacent densifying snow combined to overstress the elevation 17 plate. The new work, in itself robust, was rapidly losing vertical support. We expect to see displacements there in 1979.

The life extension work done in 1976 eliminated several serious interference problems between the truss enclosure and the structural frame. Some of the steel box walers of the truss enclosure at elevations 14, 32 and 48 were reconfigured or removed to eliminate interference with truss diagonals. This was quite beneficial and is probably one reason why the rate of secondary stress increase in the structural frame is minimal since the life extension operation (Fig. 2).

Raising the roofs of the lateral (A to N) truss enclosures in 1976 provided valuable extra clearance above the upper trusses.

Although the 1978 level of interference was minimal, it is inevitable that new interference problems will develop as the "unsupported" truss enclosure moves downward. Since the outer wall of the truss enclosure is now essentially free to move downward it may do so rapidly and numerous interference problems may generate in a few years. At DYE-3 once the truss enclosure began to telescope downward, the rates of deterioration and interference accelerated. We also expect such an increase at DYE-2 but feel it will be somewhat slower than that experienced at DYE-3. Nevertheless, the DYE-2 truss enclosure is falling apart and we feel that it is quite important to resolve this problem

within a few years. We recommend that a major life extension effort should commence not later than the summer of 1981. Perhaps some work should be accomplished sooner.

We expect that it will not be technically and economically feasible to repair or replace the lower half of the DYE-2 truss enclosure in order to achieve a life extension to 1986. However, since our expertise in construction economics is limited we suggest that Metcalf and Eddy's opinion be solicited on this question.

In order to focus future life extension work at DYE-2 we recommend that the U.S. Air Force fund a joint CRREL-Metcalf and Eddy inspection of the DYE-2 truss enclosure during the summer of 1979. Joint CRREL-Metcalf and Eddy inspections, conducted prior to the 1977-1978 DYE-3 life extension, were quite beneficial.

#### LIFE EXTENSION ALTERNATIVES

##### General

Of all the life extension alternatives studied by Metcalf and Eddy for the recent DYE-3 life extension the two most promising were:

- A sideways move onto a new undistorted foundation.
- Filling the existing truss enclosure with ice to about elevation 52; building a new truss enclosure above that elevation; severing each column at the top of the ice backfill and supporting it on a new footing at that elevation.

Although expensive, the sideways move was less costly than the alternative of an ice backfill because the latter required a new truss enclosure above elevation 52 and a new footing for each column at that elevation. Further, the installation of new footings on a 50-ft thick manufactured block of ice was considered risky by many concerned. We still consider such a foundation system to be risky.

DYE-2 is in a somewhat different situation. The truss enclosure above elevation 52 is in good condition and, providing it is not adversely affected by telescoping of the portions below during the next couple of years, it should be useful to 1986 with little extra work. More importantly the level of stress in the columns and the projected rate of secondary stress accumulation in the structural frame are such that it may be possible to retain the existing support system to 1986.

If the lower 50 ft of the truss enclosure were backfilled with ice it might be possible to leave the columns intact rather than sever them at the top of the ice backfill where new footings would take their load. This would eliminate a major expense and a major risk associated with this alternative when it was proposed for DYE-3.

### Ice Backfill

The DYE-2 "ice backfill" alternative would then consist of the following:

1. Remove Peak Secondary Stresses: Sway bolts would be adjusted to reduce peak secondary stresses in the columns and trusses.

2. Backfill the Truss Enclosure to Elevation 52: Water would be sprayed into the truss enclosure during the winter months and fan-induced cold outside air would rapidly freeze it during placement and cool the ice backfill. This operation would continue until the ice mass reached elevation 52. Perhaps it could be done during one winter (1980-81) but it probably would be technically acceptable to do about half during the 1980-81 winter, raise the building during the 1981 summer and complete the ice backfill the following winter.

We prefer a one component (water) system over a two-component (water and snow) slurry system even though the former will necessitate the consumption of about twice as much fuel to melt snow. We feel the water system is technically more direct, has a far better chance of creating a homogeneous backfill and will be significantly less labor intensive. It also may be faster and less expensive overall than a slurry system.

The CRREL report "Methods for Backfilling Truss Enclosures at DYE-2 and DYE-3" (Hanamoto et al. 1976) describes both alternatives in some detail. Key points mentioned are as follows:

- About 45,000 gal of fuel will be needed to melt the 2.8 million gal of water needed to fill the truss enclosure to elevation 52.
- In order to accomplish this during a 150-day period during the winter a daily snow melting capacity of about 20,000 gal is needed.
- Thermally it seems possible to raise the ice surface about 5 in./day when cold outside air is used to freeze and cool the sprayed on water.
- Work can probably proceed from mid-October to mid-April.

3. Sever Lower Truss Diagonals: Perhaps the diagonals of the lower truss just below the double collar should be cut away so that any displacement of the ice mass in which they are embedded, can not induce stresses on the columns and upper trusses.

4. Rehabilitate the Truss Enclosure Above Elevation 52: Minor modifications would be made to the truss enclosure above elevation 52 as necessitated by displacement from now until the life extension operation.

At the current rate of snow buildup, footing settlement and snow densification, the "net build-up rate" (Tobiasson et al. 1974) at DYE-2

is 3 ft/year. At this rate the top of the existing truss enclosure will be a foot or two below the expected snow surface in 1986. This suggests that it would not be necessary to extend the existing truss enclosure upward until that time.

5. Raise the Building: The building will be about 19 ft above the expected snow surface in 1981 and should be raised then. The total lift needed to secure a life extension to 1986 is only 12 ft.

When DYE-2 is elevated less than 15 ft above the surrounding snow, snow accumulation around it increases noticeably. If it were not lifted in 1981, a very large snow removal operation would be necessary beyond 1983. If 1986 were the absolute end of the usefulness of DYE-2, it might be economically feasible to accept this burden rather than to invest in the expense of raising the building further in 1981. However, we recommend against this approach since historically the useful life of DYE-2 has been continuously extended and the extra cost of extending the life beyond 1986 would be increased significantly if no lift were performed in 1981 or 1982.

The building needs to be lifted only 12 ft to extend its useful life to 1986. It may be possible to achieve a 12-ft lift without the need for new trusses. If new trusses are necessary, it is recommended that they be suspended below the building similar to the new trusses at DYE-3. If such trusses are needed at DYE-2 it may be advisable to raise the building more than the 12-ft minimum requirement and install stronger-than-necessary external trusses with the idea that in 1986 all lateral loads could be taken by them with the entire truss enclosure backfilled with ice. This would eliminate the need for all subsurface trusses and truss enclosures after 1986. At that time neither DYE-2 nor DYE-3 would have subsurface trusses or truss enclosures. DYE-2 would be supported on what might be termed iced-in "piles" and DYE-3 on its 1977 vintage spread footings.

The ice backfill alternative is attractive enough at DYE-2 to warrant its consideration at that station even though it was previously rejected at DYE-3.

#### Sideways Move

The 210-ft sideways move of DYE-3 in 1977 could be repeated for DYE-2. Temporary footings, portions of the girders, column support brackets, rollers, and all hydraulic jacks and controls are stockpiled in Sondrestrom ready for possible reuse at DYE-2. Since the DYE-3 sideways move was accomplished with relative ease many of the concerns expressed prior to that job can be set aside for DYE-2. The DYE-3 success should also stimulate tighter bidding for a repeat move at DYE-2.

A sideways move of DYE-2 would not require rehabilitation of the A1-N1 truss enclosure as was accomplished at DYE-3 prior to the move.

One important difference exists at DYE-2 that should be considered if a sideways move is contemplated. In the summer it can get very warm at DYE-2. That warmth could cause the snow that supports the new footings

to consolidate faster than at DYE-3. Also, there have been occasions of heavy rain at DYE-2 during the summer months. With the snow surface configured as it was at DYE-3 during the move, this rain could drain alongside the footings and perhaps undermine them. Therefore we feel it would be necessary at DYE-2 to erect 8 to 12-ft high temporary plywood retaining walls alongside each row of the new footings and back-fill alongside. This would divert surface drainage away from the footings and insulate them from the summer warmth. White tarpaulins could be placed over the girders and attached to these retaining walls to shade the footings. The enclosed spaces thus created could be cooled, if necessary, by drawing cold air from the base of the truss enclosure into these spaces with mine exhaust fans. Figure 4 is a sketch of the protection envisioned.

The few core samples taken at DYE-2 in 1975 and returned to CRREL for strength testing showed that the snow over which the building would be moved contains massive ice lenses, zones soaked with petroleum products and a few layers of weak granular depth hoar. Most of the supporting material, because it contains refrozen meltwater, is denser and much stronger than the supporting snow at DYE-3. However very weak layers that might crush or slip upon loading may also exist at DYE-2. Additional core samples should be taken and tested along the path of the sideways move at DYE-2 to better establish the conditions of the supporting snow. We recommend the inclusion of such work in our 1979 field program.

If meltwater problems can be eliminated and solar warming can be minimized, it is expected that a safe foundation system can be created for the sideways move of DYE-2. Such a foundation system should experience about the same order of settlement as that experienced during the sideways move of DYE-3. CRREL measurements indicate that this was less than 1/2 in.

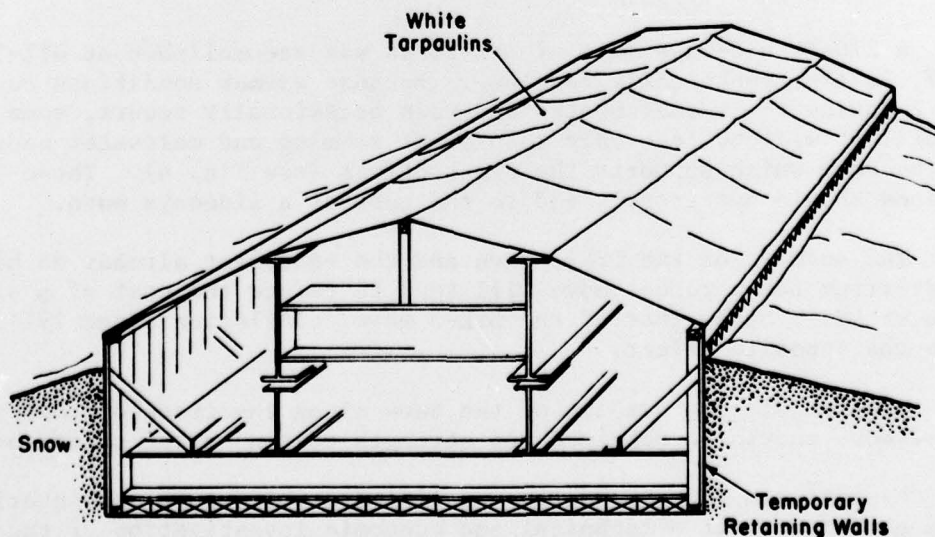


Figure 4. Retaining walls and a white fabric cover would be needed along the DYE-2 new footings to keep them cool and dry during the warm summer months.

## SUMMARY AND CONCLUSIONS

The structural steel frame of DYE-2 is overstressed in a few areas but the rate of secondary stress increase with time appears to be slight. Because only one comprehensive set of sway bolt measurements has been made since the 1976 life extension operation, additional measurements are needed in 1979 to verify this trend.

If secondary stresses are not accumulating rapidly in the structural steel frame it may be possible to use the existing structural system to 1986. If this is done the truss enclosure is the big life extension weak link. It is in bad condition and will not last until 1986. A joint CRREL - Metcalf and Eddy truss enclosure inspection should be conducted in 1979 to verify this.

Currently we feel that it is probably not economically feasible to extend the useful life of the entire truss enclosure since this would necessitate replacement of most of the truss enclosure below elevation 52. The truss enclosure is in good condition above elevation 52. One possible method of retaining the good upper portion of the truss enclosure would be to encapsulate the lower portion in ice. This alternative was not selected at DYE-3 because of the cost of building a new truss enclosure above elevation 52 and the risk and expense of creating new footings at the top of the ice backfill. At DYE-2 no new truss enclosure would be needed above elevation 52 so this expense could be avoided. The level of secondary stress in the steel frame appears to be relatively stable. This might allow encapsulating the steel frame up to elevation 52 without the need for severing the columns at that elevation and establishing new footings on top of the ice backfill. Technically and economically this is appealing.

No matter what alternative is used to extend the life of DYE-2 to 1986, the building will have to be raised in 1981 or 1982. However, a lift of as little as 12 ft should suffice.

A 210-ft sideways move of DYE-2, as was accomplished at DYE-3 in 1977, is also technically feasible. Because warmer conditions occur at DYE-2 during the summer months and rain occasionally occurs, some additional provisions will be necessary to prevent warming and meltwater undermining of the snow which supports the new footings (see Fig. 4). These provisions should not greatly add to the cost of a sideways move.

The success of the DYE-3 move and the equipment already on hand in Sondrestrom for a repeat move will tend to reduce the cost of a sideways move at DYE-2 below that of the DYE-3 move. Inflation since 1977 will have the opposite effect.

Additional core samples of the snow along the track of the proposed DYE-2 move should be obtained and strength tested in the summer of 1979.

Metcalf and Eddy or another qualified architectural-engineering firm should conduct a technical and economic investigation of the ice backfill and sideways move alternatives during 1979 and should recommend a course of action to the Air Force early in 1980.

A time chart showing both alternatives is presented in Figure 5.

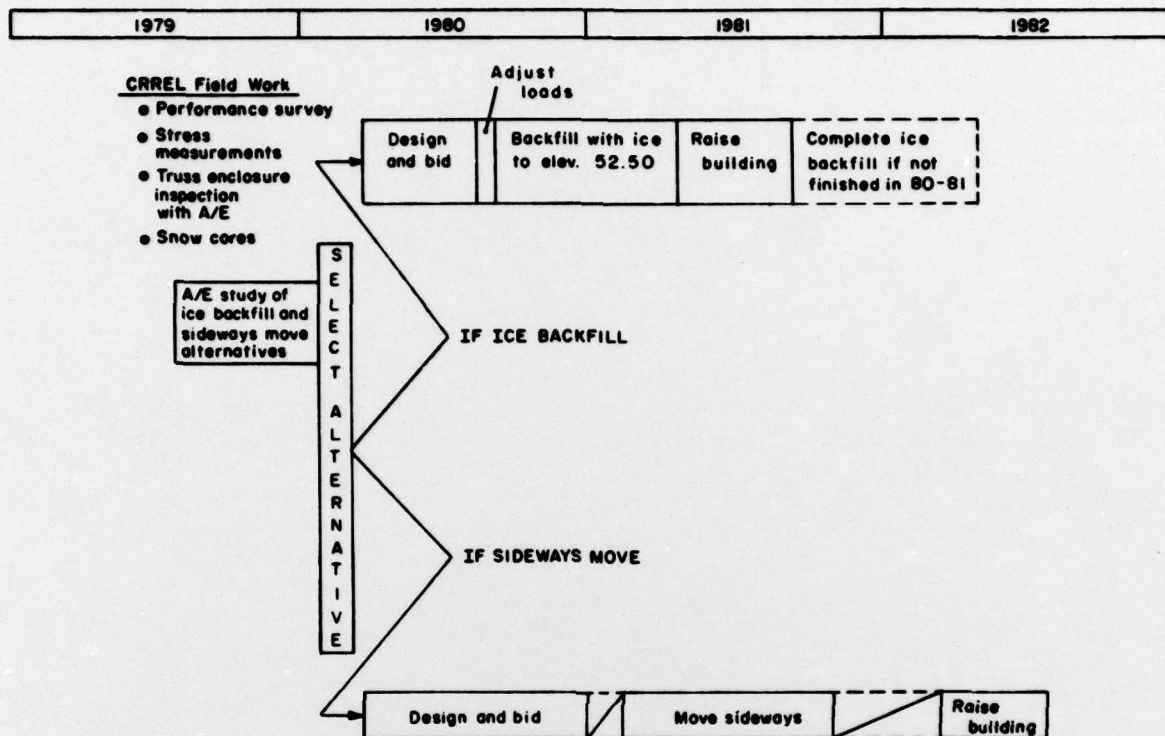


Figure 5. Time chart for DYE-2 work showing both the ice backfill and sideways move alternatives.

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